the cambrian engineering group limited

FINAL REPORT

BY

THE CAMBRIAN ENGINEERING GROUP LIMITED

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Investigate Dust Measuring Techniques and Identify Dust Levels and Effects on Safety, Operator Efficiency and Cutting Maching Performance in Potash Mines

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0.0 PREAMBLE

This report has been prepared for Energy, Mines and Resources Canada (EMR), under the terms of contract DSQ83-00170. The object of the project was the investigation of dust level measuring techniques and the identification of dust levels and effects in potash mines.

The report is presented in two parts. Part One is concerned with sampling methods, techniques and equipment. It is based on a report E-906-1-E-85, produced by the Saskatchewan Research Council as a sub-contract to Cambrian Engineering under this project. Some minor modifications have been made by Cambrian following review by EMR. These modifications in no way alter the data collected but represent a slight difference in interpretation of the results.

Part Two deals with the dust levels as such and attempts to correlate these with mining methods as well as providing some subjective observations concerning the effects of dust levels on operations.

The report is in no way concerned with the effect of dust levels on health of miners since this is outside the scope of this study.

1 INTRODUCTION TO PART ONE

Due to the method of continuous mining adopted in all subsurface potash mines in Saskatchewan, the amount of dust generated by such mining operations tends to exceed the level found in most hard rock and coal mines because dust suppression by water spray cannot be used. Thus, the success of dust control depends on reduction of dust at the source of generation and adequate ventilation measures.

In the potash mining industry, a conventional method of total dust filter-gravimetric analysis has been commonly used. The use of other instruments for dust measurement has been attempted, but the performance of such instruments is still to be fully investigated. The problems usually encountered in an underground mining site are: a wide range of airborne dust concentrations at various work sites; the hygroscopicity of potash containing dust, strong air flow due to ventilation requirement affecting personal or area sampling, light scattering properties of potash containing dust, a wide range of particle sizes, the applicability of the concept of respirable dust in potash mining, and the presence of other minerals (such as crystalline quartz) in airborne dust.

Under such circumstances, it is difficult to recommend the use of any dust samplers now on the market without a thorough investigation of field performance. One of the initial requirements under this research contract is a literature survey to determine possible methods (and instruments) for measuring dust levels in potash mines, and to propose a program of field evaluation of candidate samplers suggested for test by the client.

This report contains a summary of the literature review, as Phase I of the study, focused on the most critical problems in potash dust sampling (underground mining site only) intended for the area sampling. Additional factors may be added to the problems associated with the breathing zone

personal sampling. A proposed program of field evaluation is based on the results of the literature review indicating certain limitations of candidate samplers (Table 1).

The concept of 'respirable dust' for potash mine environment has not been recommended. The concept of 'total dust' sampling has been used. However, total dust samplers do not have clearly defined entry characteristics for coarse dust. The concept of 'inhalable dust' is now being introduced and is expected to replace it. Inhalable dust samplers are intended to match the entry characteristics of the human nose and estimate the total dust burden.

This report also presents the result of field studies made during the four site visits in comparing three each of the dust samplers for inhalable and respirable dust. The report only covers subjects identified under a subcontract program performed within the scope of this study.

1.1 CLASSIFICATION OF DUST

1.1.1 Historical Background

In 1962, U.S. Atomic Energy Commission, meeting on respirable dust sampling, defined respirable dust as "that portion of the inhaled dust which is deposited in the non-ciliated portions of the lung". This application of the concepts of respirable dust and concomitant selective sampling was intended only for insoluble particles which exhibit prolonged retention in the lung. It was not intended to include dusts which have an appreciable solubility in body fluids and those which are primarily chemical (Lippmann and Harris, 1962).

With the exception of the small quantities of quartz and other insoluble materials (such as metals and other diesel exhaust effluents), the dust found in potash mines is highly soluble. Thus, respirable dust as defined above is largely irrelevant.

The current method widely used in potash mines involves sampling total dust by means of downward facing open cassette. In this study sampling has been for both total dust and for respirable dust which is defined for the purposes of this study as the dust collected by the horizontal elutriator and the ACGIH cyclones.

Sampler acceptance curves based on the partitioning principles of ACGIH (10 mm nylon cyclone) and MRE (horizontal elutriator) indicate that the 10 mm cyclone operated at 1.7 L.P.M. achieves 50% retention efficiency at particle size of 3.5 microns aerodynamic equivalent diamter, and that the MRE horizontal elutriator operated at 2.5 L.P.M. achieves the same retention efficiency at 5.0 microns aerodynamic equivalent diameter.

The size cut is not sharp. Particles above 10um do not reach the alveolar region and ISO recommends that one of the two respirable size selection specifications may be used BMRC or ACGIH with 50% cuts at 5.0um and 3.5um aerodynamic equivalent diameters respectively.

1.1.2 Consideration of Chemical Composition

The constituents of dust may be discussed according to the definition by the U.S.A.E.C. The definition is not intended for appreciable solubility in body fluids and those which are primarily toxic chemical.

A previous study indicats that the insoluble mass fraction of the total dust suspended is 0.1 to 0.6% (Markham, et al, 1981). This means that 99.4 to 99.9% of the dust mass in suspension is water soluble. The clay content was assumed to be of the order of 1 to 10% mass of the ore in the mine studied. Clusters of the clay, during the cutting operation, could break into fine sizes of single crystalline particles and be removed from the ambient air of the work space by following the rapid air stream of ventilation, because of their fine size. They also will stay in the air longer because of the small size.

Interpretation of chemical toxicity in the definition needs further explanation in the case of highly water soluble dust. The toxicity of agents (potassium chloride or sodium chloride as major ingredients) through chemical reactions must be further clarified in terms of short time acute toxicity or chronic toxicity in respiratory exposure. These two salts are apparently not toxic in as far as the inhalation of the potash dust is concerned. However, as the report indicates, these constituents act as irritants not only by inhalation but also in other ways of exposure, such as dermal, nasopharyngeal, or eye irriation.

The exclusion of the water soluble mass from the total mass of finer size range has not been justified.

1.2 SAMPLER PERFORMANCE DISCREPANCY

1.2.1 Conditions of Simultaneous Sampling

Previous studies have indicated that there was consistent discrepancy of the mass of dust collected as respirable dust between cyclones of nylon or metallic material and MRE gravimeteric sampler with horizontal elutriator. The ratio in the dust concentration between two types of instruments varied from 0.3 to 1.00.

The expectation in side by side comparison sampling is that:

a) On average both instruments are exposed to the same dust concentration;
b) Both instruments are exposed to the same fluctuations in concentration;
c) The samplers do not interfere with each other.

In field testing these conditions can only be met approximately since the dust concentrations very significantly in space and time.

Arguments on the discrepancy or coincidence of size fractionating performance between the 10 mm nylon cyclone and the horizontal elutriator have been represented in the process of developing the 10 mm nylon cyclone technique as a size-selective sampling method in North America. However, none of the papers published up till now discussed directly the comparison of cut-off characteristics between the two instruments (Ayer, et al, 1975, Ettinger et al, 1970, Bein and Corn, 1971, Parobeck, 1972, Tomb et al, 1973a, and Knight et al, 1974).
The reference to the above listed literature confirms that there seems to be scarcely any publications positively supporting the quantitative discrepancy of these two instruments under various conditions.

Evidence found from relationships between the mass concentration of fine dust (mg/m^3) and the ratio of cyclone/elutriator fraction also indicates that the ratio is related inversely to the concentration of fine dust, however, the ratio seems to level off beyond 20 mg/m^3. The ratio thus estimated from this approximate relationship would be 2 to 3 (Markham et al, 1981).

1.2.2 Factors Contributing to the Discrepancy

(a) Particle Size

Particle size distribution of dust obtained with an Andersen Mini-sampler (cascade impactor) can be further interpreted to determine the mass median aerodynamic equivalent diameter (MMAED) and cumulative mass fraction of dust at respective cut-off diameters (3.5 microns for the cyclone and 5.0 microns for the elutriator).

Another factor contributing to the discrepancy in fitting between BMRC and ACGIH curves appears to be the value of the geometric standard deviation (Sigma G) or the particle size determined on a log-probability sheet, if the particle size distribution follows the log-normal function. If the value of Sigma G of the dust particles sampled remains between 1.5 and 4.0, the curve fitting is supposed to result in approximately 10% difference for a tidal volume. However, the size range of particles indicated in MMAED was up to 6 microns and there was no specific mention of the mode of particle size distribution (Knight et al, 1970).

A particle size distribution of dust in the miner operation was plotted on a log-probability sheet. The sample collected at the miner site was expected to be heterogeneous (higher value of Sigma G). The value of MMAED was 8.3 microns and Sigma G was 2.44. From the visual evaluation of the distribution curve, there was no sign of a steep slope and a smooth extrapolation beyond the first stage size of the Andersen sampler

was possible. This might mean that the discrepancy between the two samplers was actually created by some factors such as the high concentration of coarse dust rather than the particle size distribution (Markham et al, 1981).

(b) Inlet Orifice Geometry

Only a properly designed sampler can collect a dust sample in the original form and particle spectrum as it exists in the airborne state. The collection efficiency of an aerosol sampler is dependent on the inertia and sedimentation properties of particles in suspension, the air sampling rate, the geometry and orientation of the inlet orifice, and on the condition of ambient air or true isokinetic sampling. Therefore, a true sample of aerosol (100% efficiency of collection) is obtained only when both particle inertia and sedimentation effects are negligible.

The inertia effects of particles can be evaluated in terms of the particles' stopping distance. To minimize the particles' inertia effect in the vicinity of the orifice, the stopping distance must be les than the radius of the orifice (Bien and Corn, 1971).

The minimum permissible diameter of the inlet orifice calculated for the 10 mm nylon cyclone at 1.7 l/m of sampling dust particles of 8 microns aerodynamic equivalent diameter is 0.75 cm. However, the actual diameter of the 10 mm cyclone (circular equivalent) is 0.21 cm. It was suggested that the physical dimensions or sampling rates of commonly used aerosol samplers should be altered to ensure the efficient collection of samples. However, the flow rate of the 10 mm cyclone was set tentatively at 1.7 l/m, and only the orifice size may become a target of modification if required. The size separation of this cyclone depends on the air velocity leaving the inlet orifices, thus it would have to be tapered.

(c) Air Flow Orientation

The discussion presented above assumes calm air conditions. The behaviour of airborne particles may be more affected by the flow pattern of air, such as in the potash mine's work environment where strong air flow exists due to ventilation, than simply by these two parameters. Besides, both the cyclone and the elutriator have selective sensitivity to additional parameters. In the turbulent shear field of a cyclone sampler where fibrous particles are suspended, the particles' length may assume increased importance, whereas in the streamline fluid field of the elutriator the particle diameter dictates the behaviour. Further, problems of particle agglomeration, especially among the fine fiber diameters, were near completely solved (Bien and Corn, 1971).

(d) Overloading of Cyclone

It is not intended in this review to discuss all of these parameters in determining the discrepancy ratio between these two samplers. Instead, the collection efficiency of the 10 mm nylon cyclone may be discussed with special reference to the aspect of overloading. It has been shown that the collection efficiency increases with:

i) increasing particle size and density;
ii) increasing the speed of rotation in the cyclone cortex;
iii) decreasing the cyclone's diameter;
iv) increasing the cyclone's length;
v) drawing some of the gas from the cyclone through a duct at the dust outlet;
vi) wetting the cyclone's walls (Leith and Mehta, 1973).

It was observed in previous sampling in a potash mine, particularly at the miner site, that the inner wall of the 10 mm cyclone where the vortex of dust laden air takes places, was covered with a noticeably thick layer of deposited dust. This consequently reduced the virtual diameter of the cyclone chamber increasing the collection efficiency, or in other words the

cut-off size of dust particles was shifted toward the finer side (Markham et al, 1981).(e)Mass Concentration of Dust

The effect of aerosol concentration is believed to alter slightly the collection efficiency of the cyclone in a positive way, by assuming that the increased mass concentration to the cyclone causes the pressure drop to be lower and thereby increases the collection efficiency. The collection efficiency was studied at dust concentrations up to 100 mg/m^3, but the behaviour of the 10 mm nylon cyclone at extremely high concentrations has not been studied (Blachman and Lippman, 1972). The problems encountered in the study are not in steady condition but due to the occasional dislodging of deposited dust from the wall of the cyclone, thus instantaneously increasing the mass concentration since coarse dust is transferred to the filter.

(f) Materials and Construction of Sampler

Another factor influencing the collection efficiency of the dust sampler was recognized recently. The material used in the filter holder affected the collection efficiency depending whether it was electro-conductive or non-conductive. Plastic filter holders with the 10 mm nylon cyclone showed 25% lower collection efficiency, compared to metallic filter holder (Knight and Kirk, 1982).

A test 10 mm cyclone of identical geometry was made of electro-conductive material and a conventional (non-conductive) nylon cyclone were compared for collection efficiency of respirable dust. Both cyclones were placed in an electrostatic field. The cyclone with conductive material resulted in more consistent data and produced a more accurate representation of deposition in the human respiratory tract (Briant and Moss, 1974). The magnitude of this effect is variable, depending on both electrostatic charge of the cyclone and the total electric charge of the aerosol.

Collection efficiency of polystyrene filter cassettes was determined for beryllium aerosol using neutral, positively and negatively charged cassettes. It was recommended that the polystyrene should be charge-neutralized when collecting charged aerosols (Turner and Cohen, 1984). It is still unclear whether the airborne dust in the underground environment is electrostatically charged, though particle charging for other materials was studied (Kousaka et al, 1981).

1.3 DESCRIPTION OF SAMPLERS TESTED

1.3.1 Inhalable Dust Sampler

The three samplers evaluated for this function were as follows:

1) Open face total dust sampler conventionally used in the potash industry and generally in North America. This sampler consists of a 37 mm filter holder (cassette, Millipore M00037A0) was mounted with a 37 mm glass fiber filter (grade A, Glasrock 1062) and without a cap (open-face), oriented in a face down position at 1.9 l/m.

2) Closed face total dust sampler with entry velocity between 1 and 3 m/s similar to those conventionally used in may European countries. This sampler consists of the same holder as mounted with a 37 mm membrane filter (pore size 0.8um, Millipore AA WG03700), however, with a cover attached to the inlet orifice (closed-face), oriented side ways and aspirated at 1.9 l/m, as commonly practised. The entry velocity was 2.5 m/s.

3) Multi-directional ORB sampler intended to simulate nasal entry (Ogden and Birkett, 1978). This sampler was mounted with 47 mm glass fiber filter (Gelman Grade A), kept in an upright position and aspirated at 1.9 l/m. The characteristics of these samplers are the inlet geometry (open-face, closed-face orifice, and multi-directional) and the construction materials (plastic holder and metallic filter holder).

1.3.2 Respirable Dust Samplers

Three samplers were tested, one gravimetric and two miniature cyclones. An MRE gravimetric sampler with a horizontal elutriator (Casella, type 113A) was mounted with a 55 mm glass fiber filter (Gelman Grade A) and aspirated at 2.5 l/m.

A 10 mm nylon cyclone (Bendix BDX99) with a 37 mm plastic cassette was mounted with a 37 mm membrane filter (pore size 0.8um, Millipore AAWG 03700) and aspirated at 1.7 l/m, which was proposed for the highest size-selective performance to comply with the ACGIH respiration curve (Ettinger et al, 1970). A metallic cyclone (Casella SIMPEDS 70MK2, TI 3804) was mounted with a 37 mm fiber filter (Gelman Grade A) and aspirated at 1.9 l/m.

Two of the MRE gravimetric samplers with horizontal elutriator's were provided, on loan, by the CANMET Elliot Lake Laboratory. The model had the elutriator with flat plates, separated to give channels of dimensions such that large particles fall to the base of the channel before reaching the end. Dimensions of the four-channel model were set by the manufacturer to within small limits to give an area tolerance of $\pm$ 0.5%. A four-channel elutriator provides a 50% collection of particles with a falling speed equal to that of a five micrometer unit density sphere. The filter used was a 55 mm glass fiber (Gelman Grade A), aspirated at 2.5 l/m.

1.4 SAMPLING STRATEGIES AND METHODS

1.4.1 Sampling Strategies Used

As a standard sampling strategy, NIOSH (1977) recommends a dual sampling method for environmental surveillance of a worker's exposure, consisting of stationary sampling to determine the general air quality of work space and personal sampling to determine the worker's (inhalation) exposure. On the other hand, general area sampling only, was recommended by the Labour Canada. However, the guidelines proposed by Labour Canada are intended only for sampling of the grain handling industry, and equivalent guidelines for potash mine sampling have not been proposed at the present time by the federal or provincial government agency. Under this circumstance, it is rather difficult to determine representative locations of stationary samplers in the short time period for the potash-mine work environment. Dusts of various chemical compositions are generated from a complex geometry of sources and workers move about a great deal during the shift.

A series of samplings (general background) at various mine locations is required to establish the guidelines for general air sampling. However, in the absence of such guidelines dust sampling in the general area of mining activities appears to be adequate.

High dust areas in the underground operation are: in the vicinity of the miner; at the mobile bridge; and near the conveyor belt transfer point. Dust concentration levels determined at these sites may be a good representation of an underground operational enviorment.

Six candidate samplers were grouped: inhalable dust samplers (open-face cassette, closed-face cassette and ORB sampler); and respirable dust samplers (MRE elutriator, 10 mm and Casella cyclones) so that performance comparisons could be made within the group.

1.4.2 Sampling Method

Two sets of samplers were prepared consisting of identical samplers. Six samplers of sampling heads were mounted on a portable frame and the inlet orifices of the samplers were positioned 30 cm apart so as to avoid aerodynamic interference of samplers. The inlet orifices were positioned 1.0 m above the ground and a vacuum pump with capacity of 20 l/m was connected to each of the sampling heads by means of a manifold. The flow rate of each sampler was controlled using a needle valve in the absence of precision-made critical orifices. The flow rate of each sampler was taken prior to and after the sampling period by means of a rotameter.

The mines surveyed are at a depth of between 900 m and 1100 m below surface which in Saskatchewan is typically 500 m above sea level. Allowance for depth was made by means of calculated calibration curves rather than any absolute method.

The sampler inlets were oriented with respect to the direction of airflow. The open-face cassettes were oriented face down, all other samplers had their inlets facing the wind direction. The sampler stand was relocated whenever the assumed source of dust generation (miner or mobile bridge) travelled, indicating quasi mobile sampling. Dust samples collected on filter surfaces were maintained in an upright position so that adhesion of dust to inner wall of cassette or container might be avoided. (Table 2).

1.4.3 Desired Sampling Period

The sensitivity of the microbalance used in the Laboratory is 10ug, however, the practical limit of such a balance is 50 - 100ug to obtain sufficient accuracy. With a flow rate of all samplers used at approximately 2 l/m, the time required to collect a minimum of 0.1 mg of dust on filter for a low concentration of 1 mg/m^3 is 50 minutes. By considering expected fluctuation of dust concentration due to stoppage of

operation, the sampling period for one set of samplings was set at 120 minutes.

1.4.4 Vanadium Analysis

Vanadium is used as a tracer for diesel exhaust contaminants as it is present in diesel fuel (Leigh 1973).

Airborne particles containing vanadium oxides are collected on a mixed cullulose ester membrane filter and then dissolved by heating in a sodium hydroxide solution at 50°C for 15 minutes. The solutions of samples and standards are analysed by flameless atomic absorption spectro-photometry in a high temperature graphite atomizer (HGA) at the characteristic line of 318.4 mm for vanadium. The absorbance is proportional to the vanadium concentration.

The method was validated over the range of 0.24 to 0.9 mg/m^3 at an atmospheric temperature and pressure of 23°C and 765 mm Hg using a 25 litre air sample (Quickert et al, 1974).

1.5 RESULTS AND DISCUSSION

1.5.1 Mean Dust Concentration

The mean concentration of airborne inhalable dust was determined after a total of two hours of continuous or intermittent sampling, depending on the nature of mining operations. The dust levels at the miner's site among four samplings ranged from 32 to 550 mg/m^3. Three values obtained for the mobile bridge site ranged from 13 to 300 mg/m^3. The values of dust concentration at the transfer point determined by continuous sampling were 61 and 180 mg/m^3 (Tables 4-1 - 4-5).

These values were obtained from the open-face cassettes oriented in a face-down position. Values are from three mining sites (mining companies), however, the range of values obtained were close to data previously obtained elsewhere (Yoshida, 1981).

The sampling performance of a 10 mm nylon cyclone could be significantly shifted to the low side when the dust concentration exceeded 100 mg/m^3 (Blackman and Lippmann, 1974). There were four occasions, during the test of 10 samplings, when the concentration of inhalable dust determined by the open-face cassette exceeded the 100 mg/m^3 limit (Table 5).

1.5.2 Reproducibility of Data

All samplers tested were not connected to a vacuum source (pump) through critical orifices to control and maintain a constant flow rate for the entire sampling period. Therefore, the flow rate measured after the needle valves of each sampler might have fluctuated during the two hours of sampling period. Under such circumstances, the use of mean dust concentration in comparing the reproducibility of the data for six samplers may not be adequate. The fluctuations of pump flow rate were discussed previously. (Bartley et al, 1984).

The reproducibility of data was expressed by the ratio of the total mass of dust (inhalable or respirable) collected on the filter of one sampler to the mean mass of three (inhalable or respirable dust) samplers. The values of the mass of dust in eight or ten samplers were correlated to the mean mass and plotted on a least square distribution. The coefficent of correlationship (r) was determined for six samplers. They are: open-face cassette (r = 0.99), closed-face cassette (r = 0.95), ORB sampler (r = 0.86) for inhalable dust, and MRE eluriator (r = 0.97), nylon cyclone (r = 0.94) and Casella cyclone (r = 0.94). Samplers with the highest reproducibility were the open-face cassette for inhalable and MRE elutriator for respirable dust.

One reason for this is that these two samplers collect higher mass than the others so that the mean of the three is biased towards them. It is significant that the agreement of the inhalable sampler, ORB with the closed-face total dust sampler is better than with the open-face suggesting that European total dust sampling technique may be a better match to inhalable dust than the North American open-face technique in these coarse dust clouds.

1.5.3 Coarseness Index of Inhalable Dust

It is known that the particle size spectra of airborne potash dust have a wide range from submicron particles to coarse particles. Some of the samplers tested have problems of sampling efficiency associated with the largest particles. The ORB sampler has a limited collection efficiency for particle diameters exceeding 20um since the sampler is intended to match nasal characteristics.

Previous studies indicate that the respirable mass fraction of dust in the potash mining equipment ranged from 7 to 30% of the total mass of (or inhalable) dust. (Markham et al, 1981). If any of the samplers tested has an inherent limitation with the particle size of dust, an index called

"coarseness index" may be used. The coarseness index may be defined as the ratio of inhalable dust mass on open-face cassette to respirable dust mass (on MRE elutriator). The index for 10 samplings ranged from 2.41 to 12.17 with a median of 7.14 for the entire sampling sites and operation (Table 7 and Figure 7).

A dusty environment with high values of the coarseness index means that the dust suspended in the environment contains a larger proportion of coarse particles. Results show that coarse particles were found at the miner's site (index 4.19 to 12.17), and a more uniform size of dust (index 3.00 and 3.68) was found at the mobile bridge site. The dust generated at the transfer points had a wide spectrum of particle size (index 2.41 to 9.90). (Table 6, Figure 7). It should be noted that every care was taken to sample as close as possible to the operating position of personnel working close to points of dust generation. The very nature of the dust generated means that some of the coarser particles had already dropped out of the air stream between the point of generation and the point of sampling.

The ratio of coarse to fine dust generated differs from that reaching the sampling site. The measurements suggest that lower ratios of coarse to fine dust are associated with lower dust concentrations. This conforms to the dilution and sedimentation effects expected as the sampling site is moved away from the dust source. The correlation is not expected for sources producing differing quantities of dust or with dilution ventilation.

The values of the coarseness index determined for the open-face and closed-face cassette and of the ORB sampler were correlated with the values of the inhalable dust concentration determined with open-face cassette. The value of the coefficient of correlation for open-face cassette was $r = 0.57$ (Figure 7), values for the other two samplers resulted in wide scattering.

1.5.4 Comparison of Inhalable Dust Samplers

The mass of dust collected on the filter papers was used for comparison rather than the mass concentration because there were some possibilities of high fluctuation of flow rates during the sampling period.

1.5.5 Comparison of Respirable Dust Samplers

The dust mass collected on two cyclones was compared to that for the MRE elutriator. For each case the mean ratio was calculated by two different methods as follows:

Method (1) the mean was defined as

$$\frac{\sum r}{n} = \sum \frac{W_{ci}/V_{ci}}{W_{hei}/V_{hei}}$$

Method (2) the mean was defined as

$$\frac{\sum W_{ci}/V_{ci}}{\sum W_{hei}/V_{hei}}$$

Where
- W_{ci} = Mass collected in sample
- V_{ci} = Volume of air with sample
- W_{hei} = Mass collected in equivalent Horizontal Elutriator sample
- V_{hei} = Volume of air with equivalent Horizontal Elutriator sample

There can be large differences between the results produced by the two methods but the second method (the results of which are shown in brackets) may have less error caused by the low weight of some samples. The ratio for the 10 mm nylon cyclone ranged from 0.19 to 1.05 with a mean of 0.51 for 10 samples. The ratio for the Casella cyclone ranged from 0.13 to 1.38 with a mean of 0.40 for 10 samples. (Table 8).

The discrepancy between the nylon cyclone and the MRE elutriator has been discussed for the past decade and the values produced are for lower concentrations (up to 30 mg/m^3) in the coal mining environment. The cyclone ratio at the miner site varied from 0.18 to 1.05 with a mean of 0.49, at the mobile bridge from 0.18 to 0.32 with a mean of 0.27, and at the transfer point 0.26 and 0.52 with a mean of 0.39. The mean value for the entire operation was 0.5. These figures are consistently lower than previously obtained figures of 0.63 (Paraback, 1972, Tomb, 1973A) 0.66 (Yoshida, 1979), 0.71 (Morse, 1971), 0.72 (Tomb, 1973B), 0.81 (Lynch, 1970), 1.00 (Ayer, 1979) (Table 9). The collection efficiency of the MRE elutriator is known to be especially sensitive to the flow rate of the pump. The collection efficiency of the cyclone by pump fluctuation was also discussed (Bartley, 1984).

It was found, however, that the Casella cyclones used had entry slot dimensions which did not agree with those originally reported (Higgins and Dewell). The change from 1.6 mm to 1.2 mm would increase air velocity and cyclone particulate removal so that it would no longer match the BMRC respirable size selection specification.

1.5.6 Chemical Composition of Dust

The ratio of potassium chloride and sodium chloride in the potash dust is known, as is the content of water insoluble mass. In this study, an additional source of airborne dust in the mining site was investigated. This is the exhaust emission from diesel engines used for transport vehicles.

The insoluble portion of the dust was found to contain a portion of vanadium indicating that diesel combustion products from service vehicles are associated with the dust and hence are also inhaled with the dust. The levels detected were as shown in Table 10 which is intended to give an indication of the vanadium content of the dust samples. The range of between 0.2 and 2.0 ug/m^2 is within the limits to be expected in an industrial application where diesel equipment is in use. (Vintinnev et al, 1955).

1.6 CONCLUSIONS DUST SAMPLING

1. Mean total dust concentrations as measured on the open-face filter ranged from 32 to 550 mg/m^3 at the miner site, 13 to 300 mg/m^3 at the mobile bridge, and from 61 to 180 mg/m^3 at the transfer point.

2. Mean respirable dust concentrations as measured by the MRE gravimetric sampler ranged from 5.5 to 51 mg/m^3 at the miner site, from 2.7 to 75 mg/m^3 at the bridge conveyors, and from 14 to 19 mg/m^3 at transfer points.

3. The coarseness index of dust from 10 sampling sites ranged from 2.41 to 12.7 indicating that substantial quantities of coarse particles generated during operations became airborne and were transported to the sampling sites.

4. The study suggests that results produced by the open-face sampler are more reproducible than those from either the closed-face or the ORB sampler and that the results from the MRE horizontal elutriator are more reproducible than those from either the nylon cyclone or the Cassella cyclone. However, direct measurements of reproducibility were not made and the result may reflect the relatively higher mass of dust collected in the open-face sampler and the MRE unit as well as bias in the method (mean of three samplers) used.

5. The closed-face total dust sampler and the ORB inhalable dust sampler showed a reasonable mean agreement but a wide range of ratios in individual measurements.

6. The results from the open-face total dust sampler indicated about twice the mean concentration of the ORB inhalable dust sampler.

7. The open-faced cassette total dust sampler indicated a dust concentration 2.5 times that of the closed-face sampler.

8. The ratio of dust concentrations indicated by the nylon cyclone and the MRE gravimetric sampler was substantially less than in previous studies. Before any significance can be placed on this, individual tests must be run with more accurate individual flow measurement.

9. There was good agreement between the nylon cyclone and the Casella metal cyclone, however, the metal cyclone had a slit three quarters of the width in the original specification so that cyclone efficiency would be increased.

10. Further studies are needed in the laboratory and field to delineate the problems associated with the dust sampling mechanism of inertial samplers in high dust concentrations.

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Table 1. Number of Scientific Articles Reviewed

	Subject	Number
I	Potash Environment	
	Environmental and Occupational Aspects	4
	Dust Sampling, General Methodology	8
	Air Pollution Aspects	7
	Dust Constituents of Potash Mines	4
	Morphology of Potash and Other Dusts	2
	Chemical Analysis, Methodology	4
	Discussion on Quartz	3
	Diesel Exhaust Emission	8
	Respirable Dust Concept	7
	Subtotal	47
II	Sampling and Analytical Instruments	
	General Principles	4
	Sampling Strategies	8
	Aerodynamics of Dust Sampler	16
	Limitations of Sampler	8
	Filter-Gravimetric Method	4
	Impaction and Impingement	13
	Sedimentation	2
	Elutriation	4
	Diffusion	4
	Light Scattering	12
	Light Extinction	6
	Beta-Attenuation	2
	Electro Conductivity	4
	Piezo Electric Mass Balance	6
	Size-Selective (Cyclone)	10
	Soiling Index	2
	Electro-Mechanical Aspects	4
	Real Time Sampler	2
	Instantaneous Read-Out Sampler	3
	Subtotal	114
III	GRAND TOTAL	161

Table 2. Summary of Sampling Activities

Date	Sampling Location	Sample Identification Number					
		Open	Closed	ORB	MRE	Nylon	Casella
June 18/84	Miner	3232	3613	3255	3592	3221	3205
	Mobile Bridge	3230	3614	3256	3594	3220	3206
June 26/84	Miner, Test No. 1	3231	3616	3626	3693	3225	3220
	Test No. 2	3231	3611	3621	3591	3222	3207
	Transfer Point,						
	Test No. 1	3236	3620	3627	3595	3226	3201
	Test No. 2	3233	3612	3622	3596	3223	3208
Nov. 1/84	Miner, Test No. 1	3237	3617	3259	3608	3224	3252
	Test No. 2	3239	3619	3628	3600	3229	3211
Nov. 6/84	Mobile Bridge,						
	Test No. 1	3238	3618	3625	3599	3228	3212
	Test No. 2	3234	3614	3250	3603	3227	3202

Table 3. Specifications of Samplers Tested

Name	Model	Filter	Filter	Flow Rate (LPM)	Cut-Off Size (um)
Inhalable Dust					
Open-face Cassette	Millipore M0000 37A0	Gelman, Grade A glass fiber	37 mm	1.9	—
Closed-face Cassette	Millipore M0000 37A0	Membrane, Millipore A A W G, 0.8 um	37 mm	1.9	—
ORB Sampler	Custom Made ISA	Gelman, Grade A glass fiber	47 mm	1.9	—
Respirable Dust					
MRE Elutriator	Casella 113A	Gelman, Grade A glass fiber	55 mm	2.5	5.0
Nylon Cyclone	Bendix BDX99	Membrane, Millipore A A W G, 0.8 um	37 mm	1.7	3.5
Casella Cyclone	Simpeds 70 MK 2	Gelman, Grade A glass fiber	37 mm	1.9	5.0

Table 4-1. Summary of Sampler Performance

Sampler	Sample No.	Total Mass (mg)	Air Vol. (m^3)	Mean Conc. (mg/m^3)
18 June 1984				
Miner Site				
(Inhalable)				
Open-face Cassette	3232	3.49	0.04	92.0
Close-face Cassette	3613	0.77	0.03	23.0
ORB Sampler	3255	2.71	0.04	71.0
Mean				62.0
(Respirable)				
MRE Elutriator	3592	0.39	0.05	7.8
Nylon Cyclone	3221	0.41	0.03	12.0
Casella Cyclone	3205	0.54	0.04	14.0
Mean				11.0
Mobile Bridge				
(Inhalable)				
Open-face Cassette	3230	2.10	0.16	13.0
Closed-face Cassette	3614	0.60	0.14	4.2
ORB Sampler	3256	0.61	0.16	3.8
Mean				7.1
(Respirable)				
MRE Elutriator	3594	0.57	0.21	2.7
Nylon Cyclone	3220	0.18	0.14	1.3
Casella Cyclone	3206	0.27	0.16	1.7
Mean				1.9

Table 4-2. Summary of Sampler Performance

Sampler	Sample No.	Total Mass (mg)	Air Vol. (m^3)	Mean Conc. (mg/m^3)
26 June 1984				
Miner Site, Test No. 1				
(Inhalable)				
Open-face Cassette	3231	104.90	0.19	550
Close-face Cassette	3616	55.71	0.17	330
ORB Sampler	3626	34.13	0.19	180
Mean				350
(Respirable)				
MRE Elutriator	3593	8.61	0.25	37
Nylon Cyclone	3225	3.89	0.17	23
Casella Cyclone	3200	4.47	0.19	24
Mean				28
Miner Site, Test No. 2				
(Inhalable)				
Open-face Cassette	3231	56.60	0.15	380
Closed-face Cassette	3611	20.26	0.14	140
ORB Sampler	3621	24.98	0.15	170
Mean				230
(Respirable)				
MRE Elutriator	3591	9.65	0.19	51
Nylon Cyclone	3222	5.57	0.14	40
Casella Cyclone	3207	3.40	0.15	23
Mean				38

Table 4-3. Summary of Sampler Performance

Sampler	Sample No.	Total Mass (mg)	Air Vol. (m^3)	Mean Conc. (mg/m^3)
26 June 1984				
Transfer Point, Test No. 1				
(Inhalable)				
Open-face Cassette	3236	37.01	0.21	180.0
Close-face Cassette	3620	7.77	0.19	41.0
ORB Sampler	3627	37.11	0.21	180.0
Mean				130.0
(Respirable)				
MRE Elutriator	3595	3.74	0.28	13.0
Nylon Cyclone	3226	1.93	0.19	10.0
Casella Cyclone	3201	1.02	0.21	4.9
Mean				9.5
Transfer Point, Test No. 2				
(Inhalable)				
Open-face Cassette	3233	12.87	0.21	60.0
Closed-face Cassette	3612	5.23	0.19	28.0
ORB Sampler	3622	3.18	0.21	15.0
Mean				35.0
(Respirable)				
MRE Elutriator	3596	5.34	0.28	19.0
Nylon Cyclone	3223	1.41	0.19	7.4
Casella Cyclone	3208	1.04	0.21	5.0
Mean				11.0

Table 4-4. Summary of Sampler Performance

Sampler	Sample No.	Total Mass (mg)	Air Vol. (m^3)	Mean Conc. (mg/m^3)
01 November 1974				
Miner, Test No. 1				
(Inhalable)				
Open-face Cassette	3237	28.14	0.32	87.0
Close-face Cassette	3617	5.72	0.32	18.0
ORB Sampler	3259	14.42	0.32	45.0
Mean				50.0
(Respirable)				
MRE Elutriator	3608	6.71	0.43	16.0
Nylon Cyclone	3224	1.39	0.29	4.8
Casella Cyclone	3252	0.85	0.32	2.6
Mean				12.0
Miner, Test No. 2				
(Inhalable)				
Open-face Cassette	3239	9.01	0.29	32.0
Closed-face Cassette	3619	4.08	0.29	14.0
ORB Sampler	3628	2.14	0.29	7.5
Mean				18.0
(Respirable)				
MRE Elutriator	3600	2.04	0.38	5.5
Nylon Cyclone	3229	0.28	0.26	1.1
Casella Cyclone	3211	0.38	0.29	1.3
Mean				2.6

Table 4-5. Summary of Sampler Performance

Sampler	Sample No.	Total Mass (mg)	Air Vol. (m^3)	Mean Conc. (mg/m^3)
06 November 1974				
Mobile Bridge, Test No. 1				
(Inhalable)				
Open-face Cassette	3238	45.19	0.15	300.0
Close-face Cassette	3618	N/A	—	—
ORB Sampler	3625	20.19	0.15	130.0
Mean				220.0
(Respirable)				
MRE Elutriator	3599	14.92	0.2	75.0
Nylon Cyclone	3228	4.84	0.14	36.0
Casella Cyclone	3212	4.72	0.15	31.0
Mean				47.0
Mobile Bridge, Test No. 2				
(Inhalable)				
Open-face Cassette	3234	24.99	0.18	140.0
Closed-face Cassette	3614	N/A	—	—
ORB Sampler	3250	12.98	0.18	73.0
Mean				110.0
(Respirable)				
MRE Elutriator	3603	8.35	0.23	36.0
Nylon Cyclone	3227	1.47	0.16	9.3
Casella Cyclone	3202	1.33	0.18	7.5
Mean				18.0

Table 4.6. Overall Performance

Dust Collected mg Sample	1	2	3	4	5	6	7	8	9	10	Totals
(Inhalable)											
Open-face Cassette	3.49	2.10	104.90	56.60	37.01	12.87	28.14	9.01	45.19	24.99	324.30
Closed-face Cassette	0.77	0.60	55.71	20.26	7.77	5.23	5.72	4.08	N/A	N/A	100.14
ORB Sampler	2.71	0.61	34.13	24.98	37.11	3.18	14.42	2.14	20.19	12.98	152.45
(Respirable)											
MRE Elutriator	0.39	0.57	8.61	9.65	3.74	5.34	6.71	2.04	14.92	8.35	60.32
Nylon Cyclone	0.11	0.18	3.89	5.57	1.93	1.41	1.39	0.28	4.84	1.47	21.37
Casella Cyclone	0.54	0.27	4.47	3.40	1.02	4.04	0.85	0.38	4.72	1.33	21.02

Air Volume m^3 Sample	1	2	3	4	5	6	7	8	9	10	Totals
(Inhalable)											
Open-face Cassette	0.04	0.16	0.19	0.15	0.21	0.21	0.32	0.29	0.15	0.18	1.90
Closed-face Cassette	0.03	0.14	0.17	0.14	0.19	0.19	0.32	0.29	N/A	N/A	1.47
ORB Sampler	0.04	0.16	0.19	0.15	0.21	0.21	0.32	0.29	0.15	0.18	1.90
(Respirable)											
MRE Elutriator	0.05	0.21	0.25	0.19	0.28	0.28	0.43	0.38	0.20	0.23	2.50
Nylon Cyclone	0.03	0.14	0.17	0.14	0.19	0.19	0.29	0.26	0.14	0.16	1.71
Casella Cyclone	0.04	0.16	0.19	0.15	0.21	0.21	0.32	0.29	0.15	0.18	1.90

Mean Concentration Sample	1	2	3	4	5	6	7	8	9	10	Totals
(Inhalable)											
Open-face Cassette	87.25	13.13	552.11	377.33	176.24	61.29	87.94	31.07	301.27	138.83	170.68
Closed-face Cassette	25.67	4.29	327.71	144.71	40.89	27.53	17.88	14.07	N/A	N/A	68.12
ORB Sampler	67.75	3.81	179.63	166.53	176.71	15.14	45.06	7.38	134.60	72.11	80.24
(Respirable)											
MRE Elutriator	7.80	2.71	34.44	50.79	13.36	19.07	15.60	5.37	74.60	36.30	24.13
Nylon Cyclone	13.67	1.29	22.88	39.79	10.16	7.42	4.79	1.08	34.57	9.19	12.50
Casella Cyclone	13.50	1.69	23.53	22.67	4.86	19.24	2.66	1.31	31.47	7.39	11.06

Table 5. Summary of Sampler Performance (mg/m^3)

Sampler	1	2	3	4	5	6	7	8	9	10
Inhalable Dust										
Open-face Cassette	91.0	13.0	520.0	380.0	180.0	61.0	87.0	32.0	300.0	140.0
Closed-face Cassette	23.0	4.2	330.0	140.0	41.0	28.0	18.0	14.0	—	—
ORB Sampler	71.0	3.8	180.0	170.0	180.0	15.0	45.0	7.5	130.0	73.0
Mean	62.0	7.1	350.0	230.0	130.0	35.0	50.0	18.0	220.0	110.0
Respirable Dust										
MRE Elutriator	7.8	2.7	38.0	51.0	14.0	19.0	16.0	5.5	75.0	36.0
Nylon Cyclone	12.0	1.3	23.0	40.0	10.0	24.0	4.5	1.1	36.0	9.3
Casella Cyclone	14.0	1.7	24.0	23.0	4.9	5.0	2.6	1.3	31.0	7.5
Mean	11.0	1.9	28.0	38.0	10.0	11.0	12.0	2.6	47.0	18.0

Table 6. Reproducibility of Data for Six Samplers (mg)

Total Mass	1	2	3	4	5	6	7	8	9	10	v
Inhalable Dust											
Open-face Cassette	3.49	2.10	104.90	56.60	37.01	12.87	28.14	9.01	45.19	24.99	0.99
Closed-face Cassette	0.77	0.60	55.71	20.26	7.77	5.23	5.72	4.08	-	-	0.95
ORB Sampler	2.71	0.61	34.13	24.98	37.11	3.18	14.42	2.14	20.19	12.98	0.86
Mean	2.31	1.10	64.91	33.94	27.29	7.09	16.09	5.16	32.69	18.99	-
Respirable Dust											
MRE Elutriator	0.39	0.57	8.61	9.65	3.74	5.34	6.71	2.04	14.92	8.35	0.97
Nylon Cyclone	0.41	0.18	3.89	5.57	1.93	1.41	1.39	0.28	4.84	1.47	0.94
Casella Cyclone	0.54	0.27	4.47	3.40	1.02	1.04	0.85	0.38	4.72	1.33	0.94
Mean	0.45	0.34	5.66	6.21	2.23	2.60	2.98	0.90	8.16	3.72	-

Table 7. Coarseness Index and Mean Concentration (mg/m^3)

	1	2	3	4	5	6	7	8	9	10	Mean
Sampling Size	M	B	M	M	T	T	M	M	B	B	
Open-face Cassette	92.0	13.0	520.0	380.0	180.0	61.0	87.0	32.0	300.0	140.0	-
Closed-face Cassette	23.0	4.2	330.0	140.0	41.0	28.0	18.0	14.0	-	-	-
ORB Sampler	71.0	3.8	180.0	170.0	180.0	15.0	45.0	7.5	130.0	73.0	-
Coarseness Index	9.0	3.7	13.0	5.9	10.0	2.4	4.2	4.4	3.0	3.0	5.7

Coarseness Index = (Open-Face Mass)/(MRE Elutriator Mass)

M: Miner, B: Mobile Bridge, T: Transfer Point

Table 8. Gravimetric Mass Ratio (mg/mg)

	1	2	3	4	5	6	7	8	9	10	Method I Mean of Ratios	Method II Weighted Mean
Inhalable Dust (Open-Face Cassette = 1.00)												
Closed-Face Cassette	0.22	0.28	0.53	0.36	0.21	0.40	0.20	0.45	-	-	0.33	0.40
ORB Sampler	0.78	0.29	0.33	0.44	1.00	0.25	0.51	0.24	0.45	0.52	0.48	0.47
Respirable Dust (MRE Elutriator = 1.00)												
Nylon Cyclone	1.05	0.32	0.45	0.58	0.52	0.26	0.21	0.19	0.32	0.18	0.41	0.52
Casella Cyclone	1.38	0.47	0.52	0.35	0.27	0.19	0.13	0.19	0.32	0.16	0.36	0.46

Table 9. Cyclone Elutriator Discrepancy

Investigator	Year	Ratio	Source	Particle Size (um)	Sigma-G	Dust Conc (mg/m^3)	Environment
Lynch	1970	0.81	Lab.	0.1-10	1.1-3.0	N/A	N/A
Morse	1971	0.71	Rev.	Up to 10	N/A	30.0	Coal Mine
Paroback	1972	0.63	Rev.	N/A	N/A	3.0	Coal Mine
Tomb	1973A	0.63	Mine	Up to 10	2.35	8.0	Coal Mine
Tomb	1973B	0.72	Mine	Up to 10	N/A	5.5	Coal Mine
Ayer	1979	1.00	Lab.	Up to 10	N/A	10.7	Granite Sheds
Yoshida	1980	0.66	Lab.	Up to 200	3.5	300	Potash Mine
Present Study	1984	0.19-1.05	Mine	Up to 200	N/A	10-550	Miner
	1984	0.18-0.32	Mine	Up to 200	N/A	100-300	M. Bridge
	1984	0.26-0.52	Mine	Up to 200	N/A	60-180	Transfer P. Potash Mine
(MEAN)		0.41					
	Ratio = 10m cyclone (mg)/MRE (mg)						

Lab. = Laboratory values Rev. = review articles

Mine = mine environment

Table 10. Vanadium Concentration in Diesel Exhaust Emission

Sample	Sampling Location	Id.Number	Vanadium (mg/sample)	Vol. of Air (m^3)	Vanadium conc. (mg/m^3)
Blank	-	-	0.05	-	-
15 June	Miner	3592	0.15	0.05	2.0
26 June	Miner Test No. 1	3593	0.10	0.25	0.2
15 June	Mobile Bridge	3594	0.10	0.21	0.24
6 November	Mobile Bridge No. 1	3599	0.40	0.2	1.75
1 November	Mobile Bridge No. 1	3608	0.15	0.43	0.24

Vanadium Conc. = (Van./ sample - Blank) ÷ (Vol. of Air)

Figure 1 Reproducibility of Values

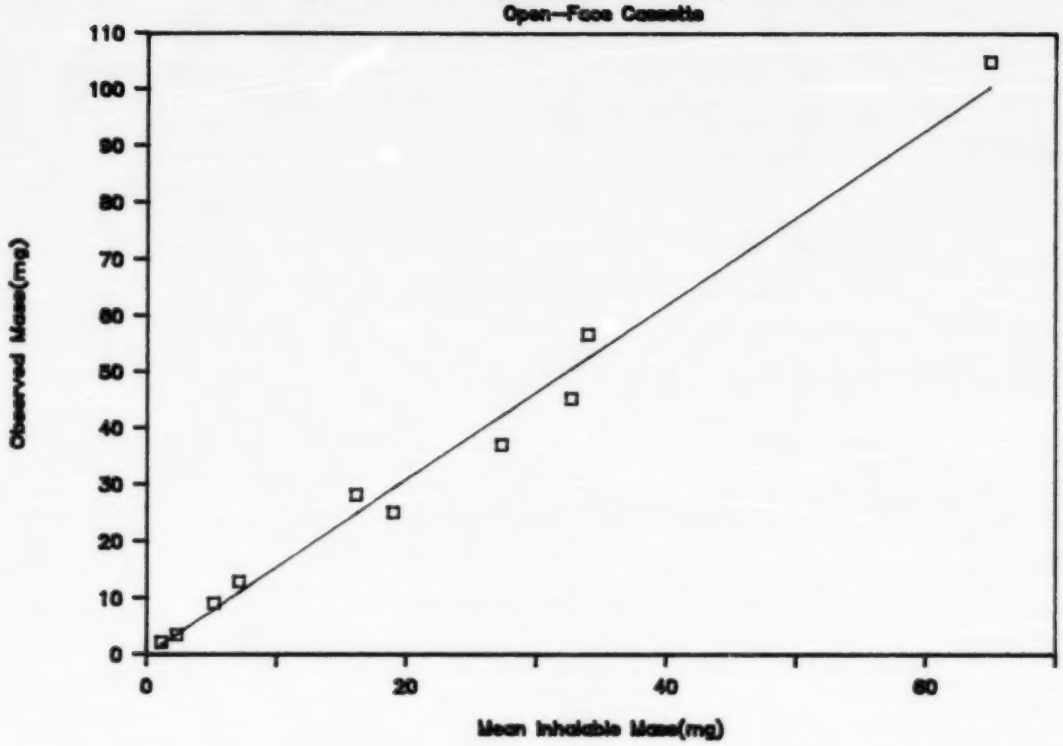


Figure 2 Reproducibility of Values

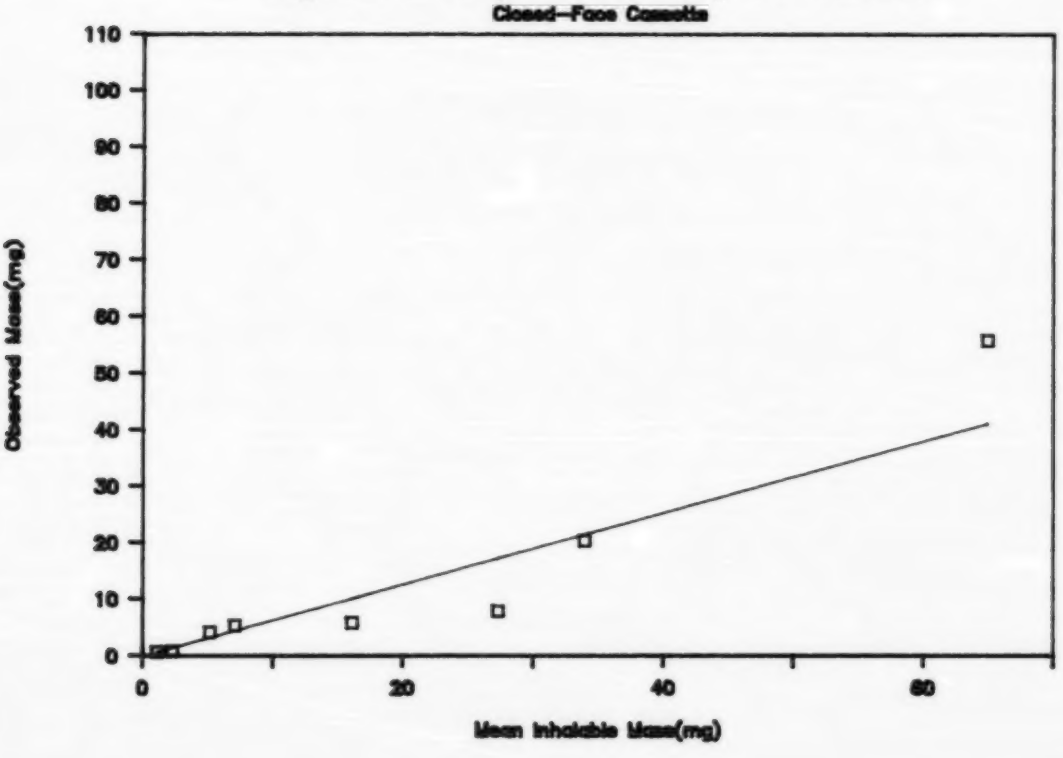


Figure 3 Reproducibility of Values

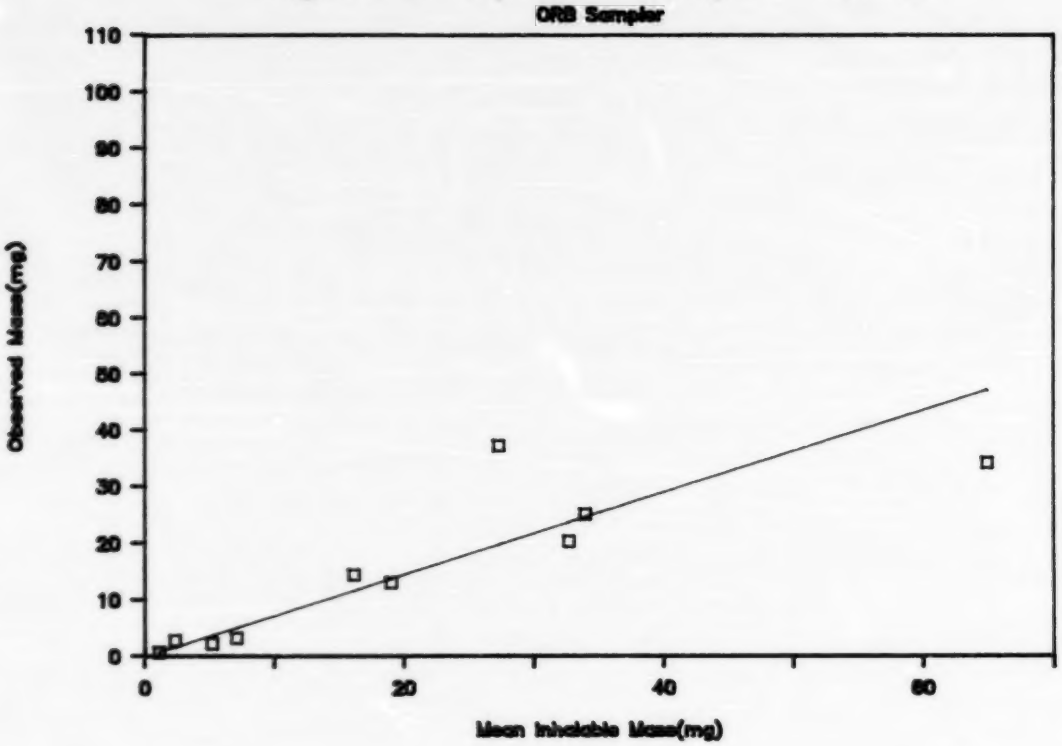


Figure 4 Reproducibility of Values

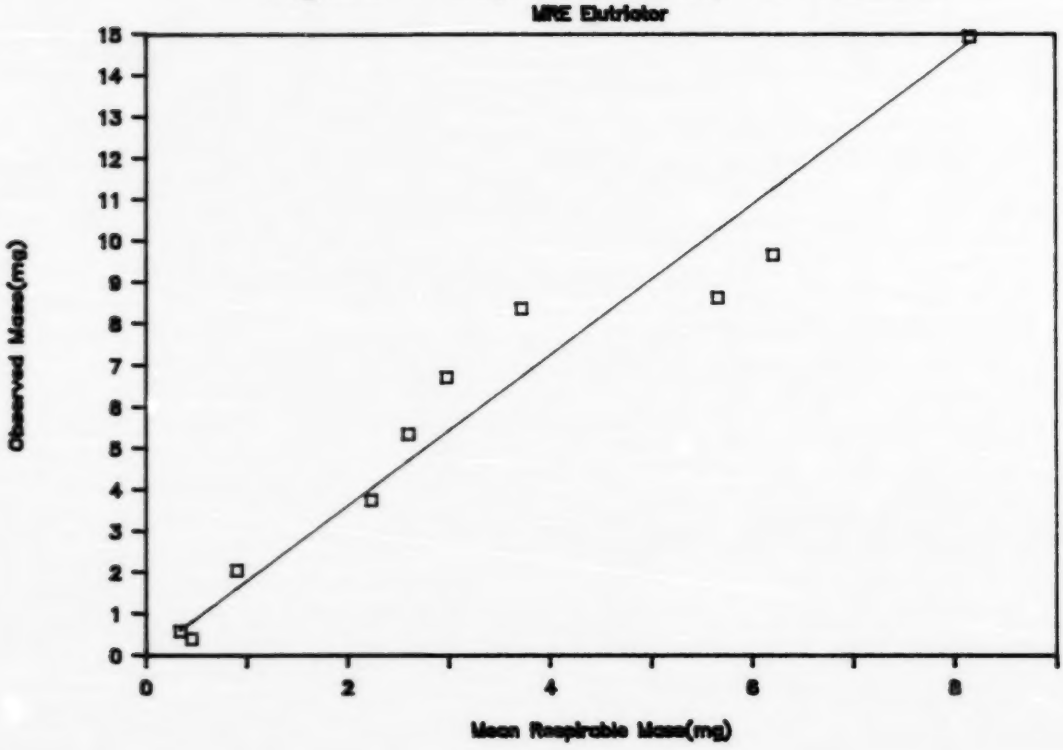


Figure 5 Reproducibility of Values

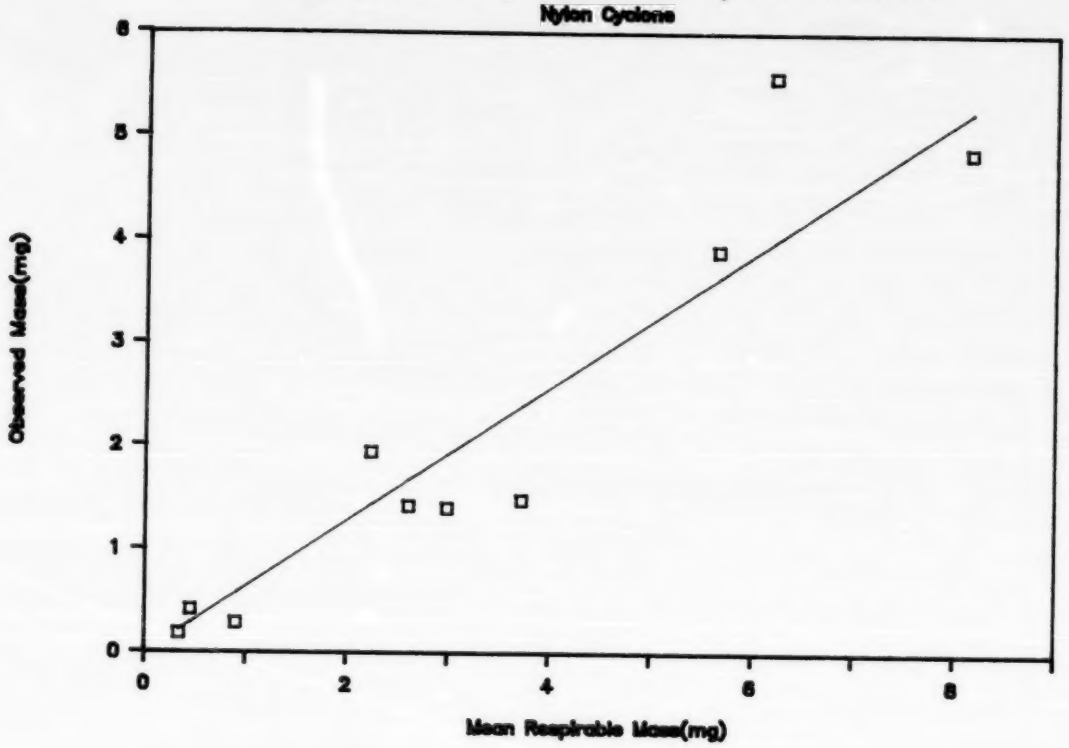
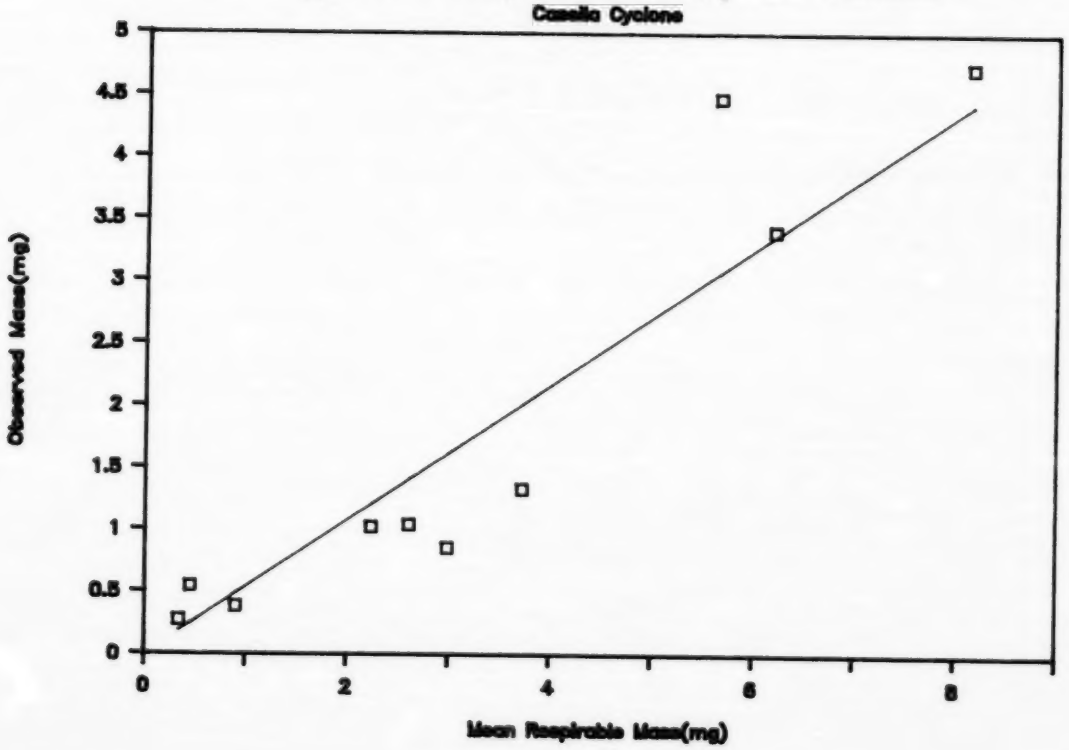
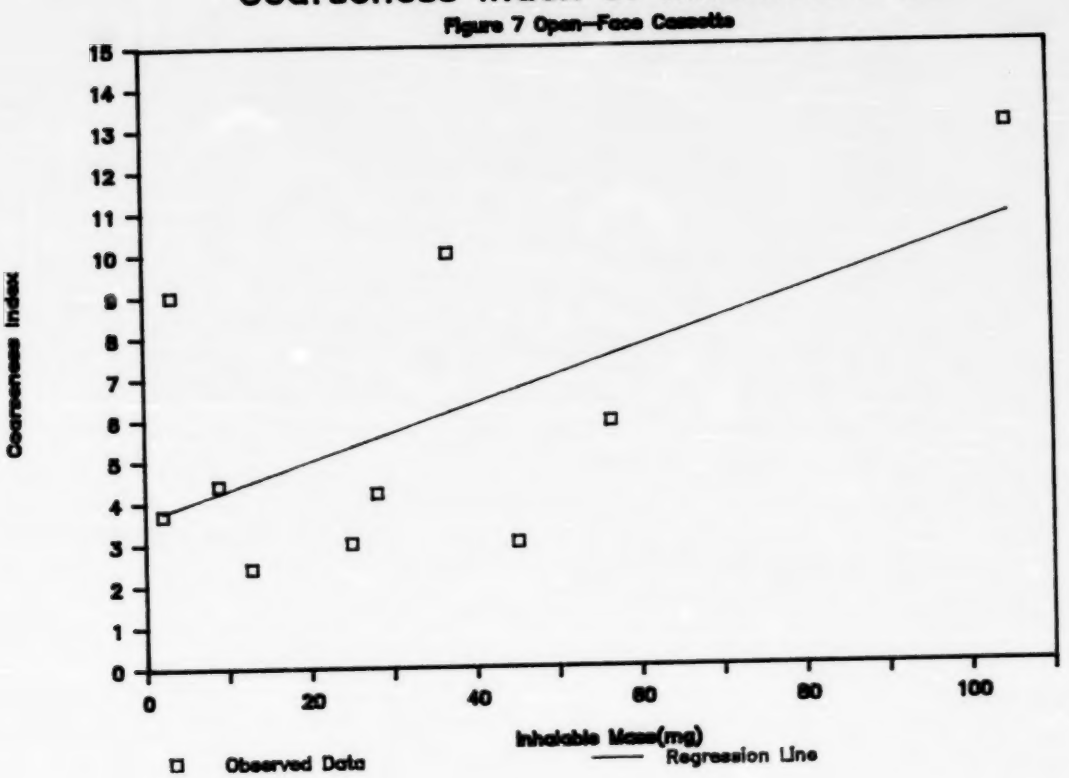


Figure 6 Reproducibility of Values




Coarseness Index of Inhalable Dust
Figure 7 Open-Face Cassette
Coarseness Index
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
20
40
60
80
100
Inhalable Mass(mg)
Observed Data
Regression Line

2 INTRODUCTION TO PART TWO

The information presented in this section is primarily the results of observation by the Cambrian personnel present at the test sites. The presence of potash ore dust is highly visible even when quantities are small. This is due to the optical properties of the salt crystals. The dust is highly soluble and has a distinct salt taste which again makes its presence very obvious.

The use of water for dust suppression in potash mines has traditionally been limited by the desire of operators to maintain a strictly dry environment due to the soluble nature of the ore bodies.

Ventilation in the mines, in Saskatchewan, is generally achieved by moving air down one shaft, through the workings and back to the other shaft. Air flow may be aided in some cases by axial flow fans with flexible ducting. The mines are developed longitudially with the workings being as much as ten kilometers from the shafts.

All mining production equipment is powered electrically with diesel powered equipment being use for service and clean up work.

2.1 GENERAL

2.1.1 General

The measurements were made during four separate visits to three different potash mines. A total of ten sets of samples was taken. This sampling is only sufficient to establish the general extent of the dust levels in the mines. A preliminary comparison of operations with dust levels is shown in Table 2.1 . The only real conclusion to be made from the data shown is that dust levels increase with production levels. The mean total dust levels identified in Part One of this report was used as a representative figure for perceived dustiness.

The following sections give observations made during the course of the sampling program. It was agreed with mine management that the individual operations would not be identified. The dates of sampling are used for reference purposes.

2.2.2 June 18, 1984

The miner in this location was a Goodman twin rotor operating in a chevron pattern using a single bridge conveyor feeding an extensible belt system. Air is supplied through the main entry and returned through the side relief entries. Water is used for dust suppression at the transfer to the bridge conveyor. The arrangement is as shown in Figure 2.1 .

The miner cutting pattern is shown in Figure 2.2 . This is typical for a two rotor machine using raplock type bits. The spacing for pencil bits is usually closer, with the objective of producting a more uniform ore gradation.

During the test period, the equipment was down for most of the time. The conditions were not noticeably dusty during the test period. The area adjacent to the miner where the samplers were located was the dustiest area.

The local ventilation system included a fan and duct providing the miner operator with fresh air.

2.2.3 June 26, 1984

The mining machine at this location was a Marietta two rotor machine using pencil bits at 65 mm spacing. The machine was cutting the first pass of straight room and pillar system as shown in Figure 2.3 . Two sets of samples were taken at the miner and at belt transfer point. The machine achieved very high production during the first sample period but there was a short break for maintenance during the second period.

The dust levels and local temperature increased noticeably during the production run. The ventilation on the machine primarily provides cooling for the motors but does provide some air for the operator. In the configuration for this pass, some dust generated in ore transfer from the machine to the conveyor system is carried forward to the operator position.

2.2.4 November 1, 1984

The mining machine studied at this location was a Goodman twin rotor using raplock tungsten carbide bits. This mine uses a chevron pattern with several mobile bridge conveyors leading to the extensible conveyor. In this case there are two 1 m mobile bridge conveyors. During the course of these tests, mechanical problems limited production. During the short time the machine was in operation, it was observed that conditions appeared to be very dusty.

2.2.5 November 6, 1984

A second set of tests were undertaken at the site outlined in 2.2.3 above. This time the machine was in full operation. Conditions appeared to be very dusty with poor visibility. The dust did not appear to be carried away well. The area of operations was generally uncomfortable.

2.3 CONCLUSIONS

The tests performed were insufficient to make any real comparison between different tooling or types of operation. The only real conclusion is that higher rates of production lead to higher dust levels and hence to reduced visibility. The perception of dust level may be varied by the ventilation pattern but again the degree of testing is insufficient to provide conclusive evidence of this.

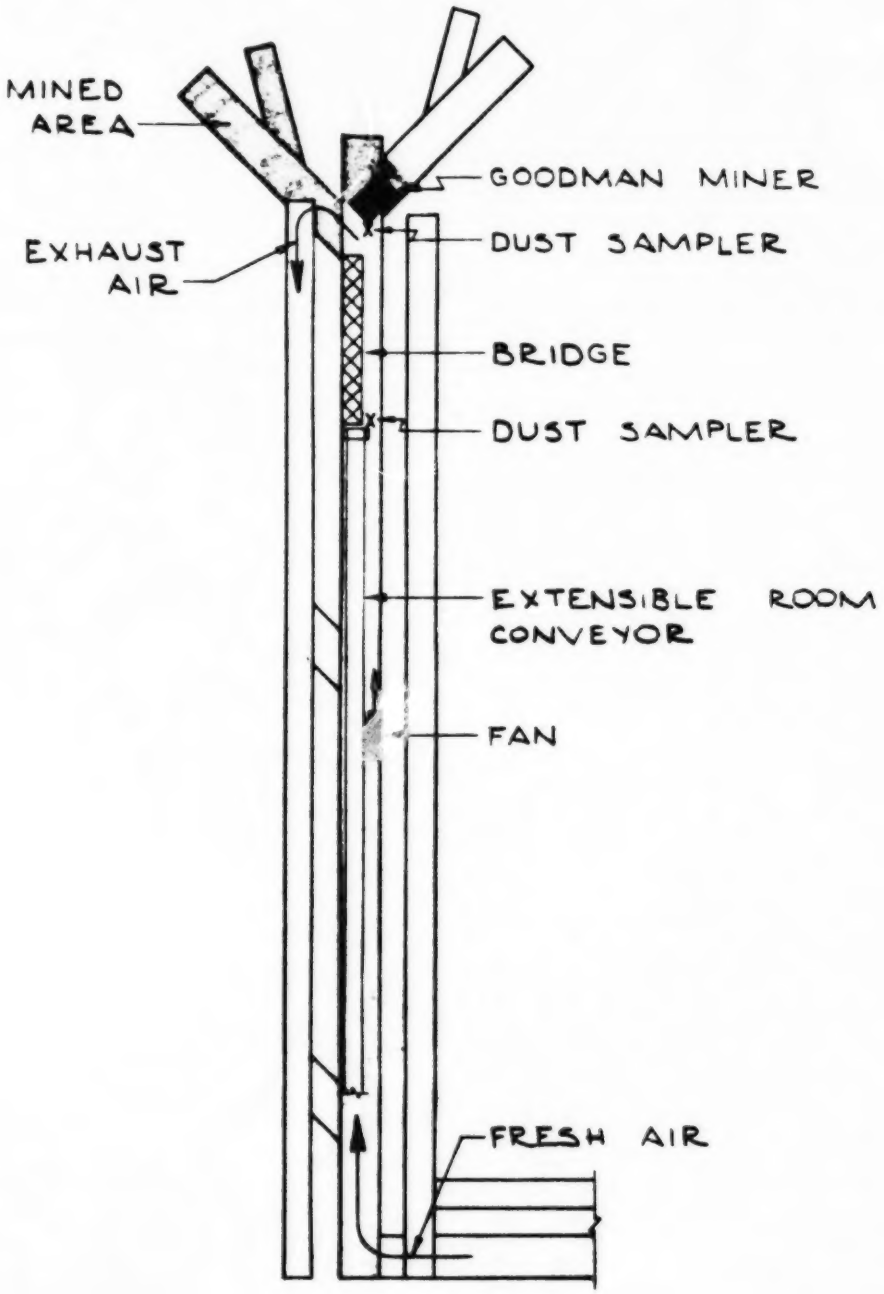
Dust levels in the area of the actual production boring machines are uncomfortably high but the effect of this on operator fatigue is uncertain. Further work may be required, particularly in the area of operator performance.

Table 2.1 Dust Sampling Techniques

Sample Date	Location	Miner Description	Tooling	Production Rate	Total Dust Mg/m^3
June 18/84	Miner	Goodman Two Rotor Chevron Pattern	Raplock Bit	Low	62
June 18/84	Transfer			Low	7.1
June 26/84	Miner	Marietta Two Rotor Single Room	Pencil Bit	High	350
June 26/84	Miner	Marietta Two Rotor Single Room	Pencil Bit	Moderate High	230
June 26/87	Transfer			High	130
June 26/87	Transfer			Moderate	35
Nov 1/84	Miner	Goodman Two Rotor Chevron Two Bridge	Raplock	Low	50
Nov 1/84	Bridge	Mobile Bridge		Low	18
Nov 6/84	Miner	Goodman Two Rotor Chevron Two Bridge	Raplock	High	220
Nov 6/84	Bridge	Mobile Bridge		High	110

FIGURE 2.1

CHEVRON PATTERN



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				Subject DUST SAMPLING SURVEY			
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FIGURE 2.2
CUTTING PATTERN

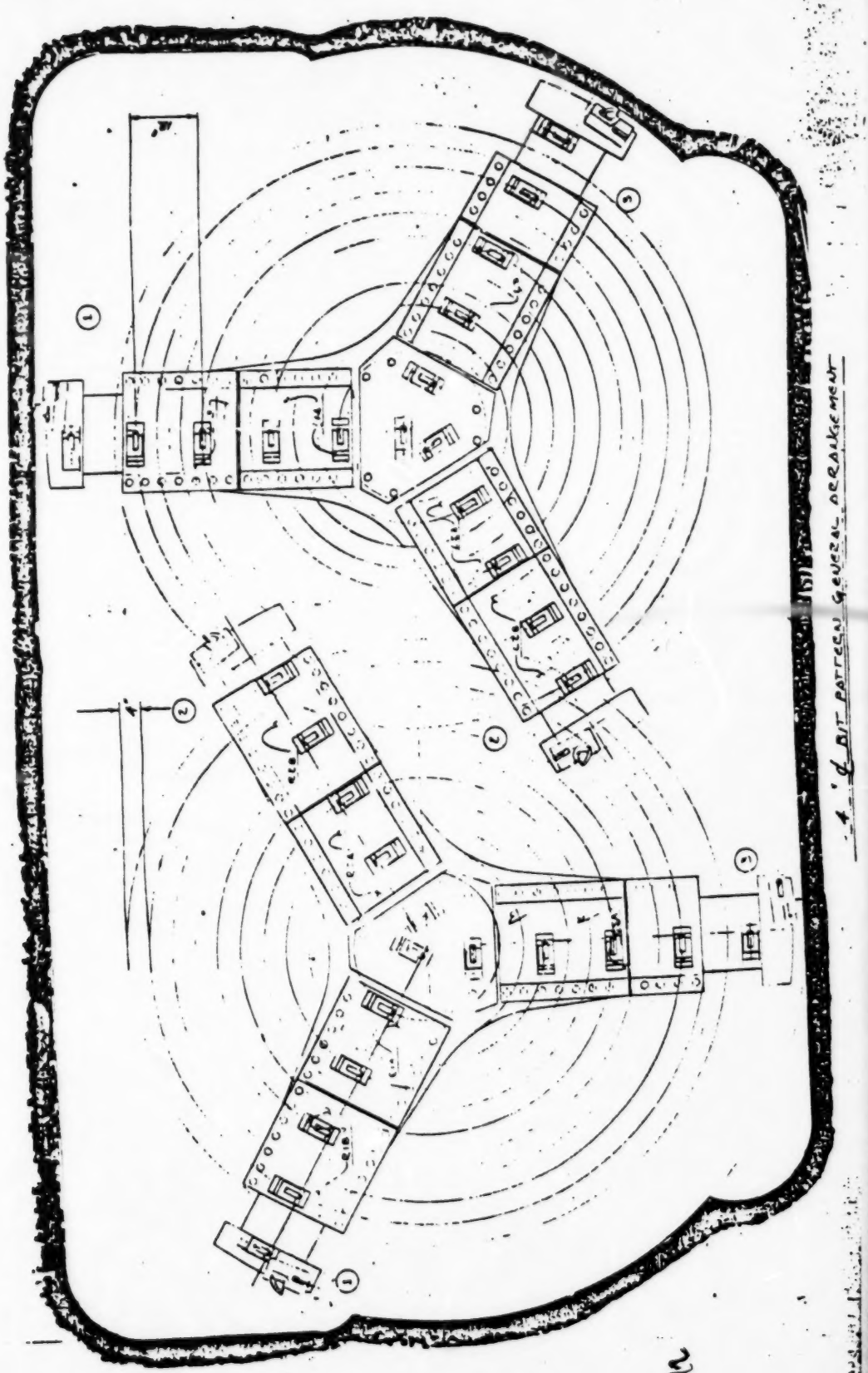
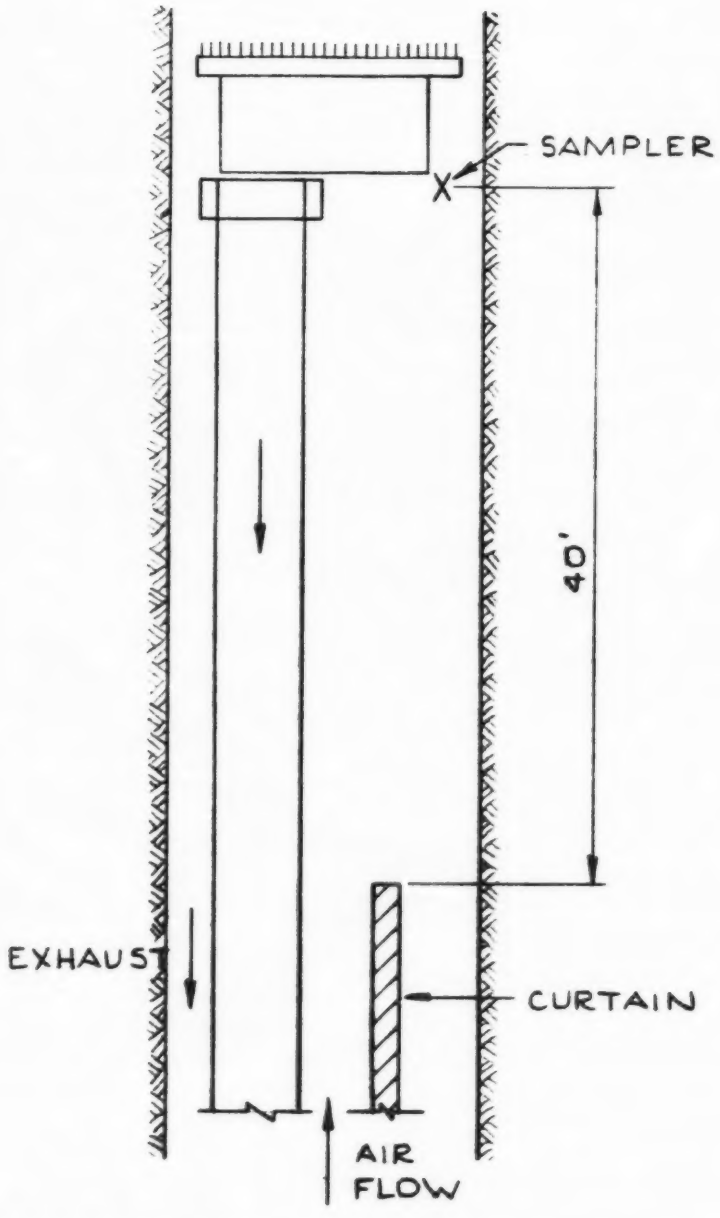


FIGURE 2.3

ROOM AND PILLAR

LOCATION #1 - MINER



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				Subject		
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